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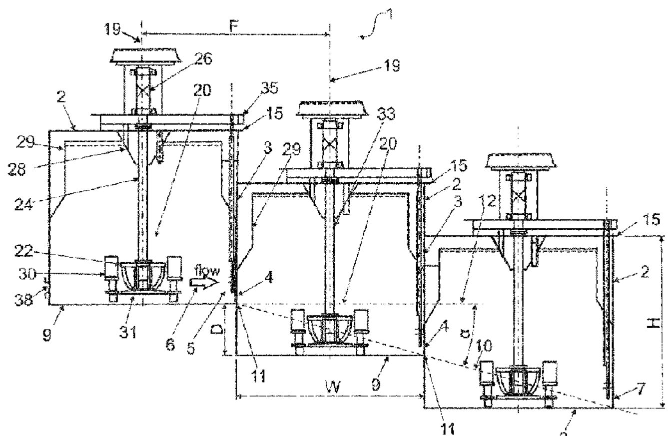

Fig. 1

(57) Abstract: A flotation device (1) and a method for processing a slurry comprising coarser sized mineral particles is presented. The flotation device comprises a plurality of flotation cells (2) in fluid communication with each other, and an inlet (38) for receiving said slurry into one of said flotation cells (2). Each of the flotation cells (2) has a wall (3) with a lower opening (4) that permits said slurry to pass from a preceding flotation cell into an entry opening (4') of a successive flotation cell (2), a slurry transfer means (39) in fluid communication with said lower opening (4) and said entry opening (4') to facilitate unimpeded slurry flow. A floor (9) of each said successive flotation cell (2) is lower than a floor (9) of said preceding flotation cell (2) to create an angle of inclination of at least 10° to induce a hydraulic gradient to drive said slurry to a discharge outlet (7) of said flotation device (1).

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A FLOTATION DEVICE AND METHOD FOR PASSING COARSER SIZED PARTICLES THROUGH A FLOTATION DEVICE

Field of the Invention

[0001] The invention relates to a flotation device and in a particular to a flotation device for processing coarser sized mineral particles. The invention has been developed primarily for use as a flotation device for processing coarser sized mineral ore particles and will be described hereinafter by reference to this application.

Background of the Invention

[0002] The following discussion of the prior art is intended to present the invention in an appropriate technical context and allow its advantages to be properly appreciated. Unless clearly indicated to the contrary, however, reference to any prior art in this specification should not be construed as an express or implied admission that such art is widely known or forms part of common general knowledge in the field.

[0003] Flotation cells are typically used in mineral processing to recover valuable mineral particles from unwanted gangue.

Summary of the Invention

[0004] According to the invention, there is provided a flotation device for processing a slurry comprising coarser sized mineral particles, comprising:

a plurality of flotation cells in fluid communication with each other;

an inlet for receiving said slurry into one of said flotation cells;

wherein each said flotation cell has a lower opening that permits said slurry to pass from a preceding flotation cell into an entry opening of a successive flotation cell;

a slurry transfer means in fluid communication with said lower opening and said entry opening to facilitate unimpeded slurry flow; and

wherein a floor of each said successive flotation cell is lower than a floor of said preceding flotation cell to create an angle of inclination of at least 10° to induce a hydraulic gradient to drive said slurry to a discharge outlet of said flotation device.

[0005] Preferably, said angle of inclination is between 10° and 65°, preferably between 13° and 50°, more preferably between 15° and 45° and most preferably is 15° to induce said hydraulic gradient.

[0006] Preferably, said angle of inclination is between 10° and 18° to induce said hydraulic gradient. In a preferred embodiment, said angle of inclination is 15°.

[0007] Preferably, there is an average angle of inclination measured from the floor of a first flotation cell in said flotation device to the floor of the last flotation cell in said flotation device, said average angle of inclination inducing said hydraulic gradient and said average angle of inclination being at least 10°. It is further preferred that said average angle of inclination being between 10° and 60°, more preferably between 13° and 45°, and most preferably 15°.

[0008] Preferably, there is a stepwise drop in said floor of said successive flotation cell relative to said floor of said preceding flotation cell, to create said angle of inclination between adjacent cells. More preferably, said stepwise drop is between 300 and 5000 mm, preferably 600 and 3300 mm. In one embodiment, said stepwise drop is 900 mm.

[0009] Preferably, there is a stepwise drop in the top of said successive flotation cell relative to the top of said preceding flotation cell, to create said angle of inclination between adjacent cells.

[0010] Preferably, each said flotation cell has the same height. Alternatively or additionally, each said flotation cell has the same width. Where the flotation cells have a circular cross-section or diameter. In one embodiment, the respective heights and widths (or diameters) of each flotation cell do not vary by more than 10 %.

[0011] Preferably, slurry transfer means comprises a common wall is shared by adjacent flotation cells to minimise blockages in said lower opening and said entry opening, said lower opening and said entry opening being formed in said common wall. Alternatively, said slurry transfer means comprises a wall from each adjacent flotation cell joined together to minimise blockages in said lower opening and said entry opening. In one embodiment, said lower opening is formed in said wall of said preceding flotation cell and said entry opening being formed in said wall of said successive flotation cell. In another embodiment, said slurry transfer means comprises a portion of a side wall of each adjacent flotation cell connected together to minimise blockages in said lower opening and said entry opening.

[0012] Preferably, said slurry flows unidirectionally in said flotation device from said preceding flotation cell to each successive flotation cell to minimise blockages in said lower opening and said entry opening.

[0013] Preferably, each said flotation cell comprises a mechanical agitator for agitating said slurry. More preferably, said mechanical agitator comprises a rotor and a stator. Alternatively, said mechanical agitator comprises a laminar flow mixer. In a further alternative, said mechanical agitator comprises a self-aspirating agitator to generate air to aerate the slurry.

[0014] Preferably, said mechanical agitator is connected to an aeration system for aerating said slurry and generating said froth.

[0015] Preferably, the floors of said flotation cells are the same to create uniform angles of inclination between each adjacent flotation cells.

[0016] Preferably, at least one floor of the floors of said flotation cells, or part of said at least one floor, is curved, planar, inclined, U-shaped or V-shaped.

[0017] Preferably, there are at least two flotation cells, preferably at least three flotation cells and more preferably at least four flotation cells.

[0018] Preferably, the coarser sized mineral particles have a P80 of 250 µm to 2 mm, preferably 300 µm to 1500 µm, more preferably 350 µm to 1000 µm and most preferably 500 µm to 750 µm, and a D50 of 100 µm to 1000 µm, preferably 150 µm to 750 µm, more preferably 1750 µm to 500 µm and most preferably 200 µm to 300 µm.

[0019] A second aspect of the invention provides the use of a flotation device according to the first aspect of the invention to process a slurry comprising coarser sized mineral particles having a P80 of 250 µm to 2 mm, preferably 300 µm to 1500 µm, more preferably 350 µm to 1000 µm and most preferably 500 µm to 750 µm, and a D50 of 100 µm to 1000 µm, preferably 150 µm to 750 µm, more preferably 175 µm to 500 µm and most preferably 200 µm to 300 µm.

[0020] A third aspect of the invention provides a method processing a slurry comprising coarser sized mineral particles in a flotation device comprising a plurality of flotation cells in fluid communication with each other, wherein each said flotation cell has a lower opening and an entry opening, an inlet for receiving said slurry into one of said flotation cells, a discharge outlet, and a slurry transfer means in fluid communication with said lower opening and said entry opening, said method comprising the steps of:

introducing said slurry through said inlet;

permitting said slurry to pass from a preceding flotation cell through said lower opening via said slurry transfer means into said entry opening of a successive flotation cell; and

arranging said flotation cells so that a floor of each said successive flotation cell is lower than a floor of said preceding flotation cell to create an angle of inclination of at least 10° to induce a hydraulic gradient to drive said slurry to said discharge outlet.

[0021] The method of this aspect of the invention has the preferred features of the first aspect of the invention, where applicable.

[0022] Preferably, said coarser sized mineral particles are mineral ore particles having a density of at least 2000 kg/m^3.

[0023] Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising", and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

[0024] Furthermore, as used herein and unless otherwise specified, the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

Brief Description of the Drawings

[0025] Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0026] Figure 1 is a cross-sectional view of a flotation device according to an embodiment of the invention;

[0027] Figure 2 is a plan view of the flotation device of Figure 1;

[0028] Figure 3 is a partial cross-sectional view of the flotation device of Figure 1;

[0029] Figure 4 is a perspective view of an auxiliary agitator that can be used in the embodiment of Figure 1;

[0030] Figure 5 is a cross-sectional view of a flotation device according to another embodiment of the invention;

[0031] Figures 6a and 6b are partial cross-sectional views of valve arrangements for flotation devices according to embodiments of the invention; and

[0032] Figures 7a to 7e are schematic cross-sectional views of different floors that can be used in the flotation cells of the flotation device according to other embodiments of the invention.

Preferred Embodiments of the Invention

[0033] The present invention will now be described with reference to the following examples which should be considered in all respects as illustrative and non-restrictive. Referring to Figure 1, a flotation device 1 comprises a plurality of flotation cells 2. A slurry transfer means is located between each of the flotation cells in the form of a common wall 3 shared by adjacent flotation cells. Each common wall 3 has a lower opening 4 at its lower end 5 for enabling the slurry to flow unidirectionally (i.e. in a single direction) as generally indicated by arrow 6 through the flotation device 1 from one flotation cell 2 to the next successive flotation cell downstream towards a discharge outlet 7. The unidirectional flow assists in minimising blockages in the lower opening 4. The common walls 3 facilitate unimpeded slurry flow from the lower opening 4 of a preceding flotation cell 2 into the successive flotation cell, thus inhibiting or preventing sanding occurring between adjacent flotation cells. The common wall 3 also helps to minimise blockages in the lower opening 4, which also acts as an entry opening for each successive flotation cell 2. In other embodiments there may be a separate entry opening in the common wall 3.

[0034] As best shown in Figure 2, the common wall 3 of each flotation cell 2 is generally planar, whereas the remaining walls 8 of each flotation cell are arcuate or circular in cross-section. It will be appreciated that in other embodiments, the walls 8 of the flotation cell may also be planar to define rectangular, square, triangular, hexagonal, pentagonal and other polygonal cross-sections. The common walls 3 and lower openings 4 enable each flotation cell 2 to be connected to an adjacent flotation cell without the need for any connection duct that could cause sanding problems. Hence, each flotation cell 2 has an internal fluid connection with the next flotation cell in line.

[0035] In other embodiments, the slurry transfer means comprises separate walls of adjacent flotation cells 2 joined together, instead of each flotation cell 2 sharing the common wall 3 with the next flotation cell in succession.

[0036] In a further embodiment, a portion of a side wall of each adjacent flotation cell are connected together to form the slurry transfer means by creating a common wall. That is, adjacent flotation cells may have sidewalls that have respective portions that diverge from each other but are connected at another portion to define the common wall.

[0037] The flotation cells 2 each have floors 9 that are lower than the floor of the preceding flotation cell. This creates an effective angle of inclination α that creates a hydraulic gradient that drives the flow of the slurry through each flotation cell 2 under gravity. As a result, there is little or no risk of sanding up of the lower opening 4, even where the particle size of the slurry increases up to 2mm in diameter. Hence, the flotation device 1 is able to process coarser particles of greater particle size than conventionally possible.

[0038] The angle of inclination α is measured from a line 10 intersecting the edge 11 of each floor 9 relative to the horizontal plane 12. Generally, the horizontal plane 12 is coincident with the floor 9 of the first flotation cell. Preferably, the angle of inclination α is between 10° and 18°, and it is particularly preferred that the angle of inclination is 15°, as it has been found that this angle is optimal to create the hydraulic gradient without excessively increasing the distance between respective floors 9 of the flotation cells 2.

[0039] In this embodiment, the floors 9 of each successive flotation cell 2 drops stepwise by a distance D relative to the floor of the preceding flotation cell, as best shown in Figure 3. The stepwise drop facilitates creation of the angle of inclination α. Where the distance of the flotation cells 2 is 3500 mm and the flotation device 1 comprises three flotation cells 2 as illustrated in the Figures 1 and 2, this stepwise drop is preferably 938 mm to maintain the preferred angle of inclination α of 15°. In other embodiments, the stepwise drop will vary, depending on the size of the flotation cells, to maintain the preferred angle of inclination α of 15°, and is preferably between 300 and 5500 mm, and more preferably 600 and 3300 mm.

[0040] In the embodiment, the flotation cells 2 have the same height or depth H to maintain a uniform angle of inclination α throughout all of the flotation cells 2 in the flotation device 1. This means that there is also a corresponding stepwise drop D between the respective tops 15 of the flotation cells 2. The stepwise drop D also facilitates creation of the angle of inclination α. Likewise, it is also preferred that the width W (or diameter for flotation cells 2 having substantially circular cross-sections) is also constant for each flotation cell. In one embodiment, the height and diameter of the flotation cells 2 do not vary by more than 10 %. It is contemplated that while in most applications there is a constant height to width ratio, in other particular applications the ratio may vary by up to 15 %. The flotation cells 2 are spaced by distance F measured from the respective centre lines 19 of each flotation cell.

[0041] Each flotation cell 2 also has a mechanical agitator 20, which comprises a rotor 22 connected to a drive shaft 24 that is driven by a drive mechanism 26. The drive mechanism 26 typically comprises a motor connected to a belt drive or gearbox (not shown).

[0042] A froth deflection cone 28 is provided adjacent the top of the drive shaft 24 to direct froth generated by the rotor 22 towards an overflow launder or weir 29 for recovery of fine mineral particles, as best shown in Figures 1 and 3. For ease of manufacture it is preferred that the launder 29 is located at the common wall 3 of each flotation cell 2. In another embodiment, the launder 29 is located elsewhere along the circumference of the flotation cell 2, and is known as a perimeter launder. In other embodiments, the perimeter launder is replaced with a donut launder or centre launder located “off the wall” (i.e. spaced apart from the cell walls 3, 8) and at a fixed distance from the flotation cell centre line 19.

[0043] A modified version of the agitator 20 has an auxiliary agitator 27 connected to the drive shaft 24 at a position substantially midway between the underside of the deflection cone 28 and the top of the rotor 22, as shown in Figure 4. The auxiliary agitator 27 includes agitation blades 27a extending radially outwardly from diametrically opposite sides of the shaft 24. Each blade 27a intersects the shaft 24 at an angle of incidence of around 45° to the shaft axis X. The blades 27a are connected to the shaft 7 by a clamp 27b.

[0044] The rotor 22 induces a primary radial flow and a secondary axial flow through the slurry in the flotation cell 2. The auxiliary agitator 27 increases the secondary axial flow by inducing a downward current, which increases the secondary flow turnover rate. This, in turn, draws floatable particles that have dropped out of the froth zone down through the tank and into the mixing zone of the primary rotor, thereby increasing the probability that these particles will be refloated, and hence increasing the overall efficiency of the recovery process. Thus, the agitation blades 27a define an axial impeller to supplement the axial flow induced by the rotor 22.

[0045] A stator 30 mounted on a stator base 31 is provided around the rotor 22 to form the flotation cell agitator mechanism. In other embodiments, the mechanical agitator comprises a laminar flow mixer instead of a rotor 22 and stator 30. In yet another embodiment, the mechanical agitator is a self-aspirating agitator, which generates its own air supply to aerate the slurry. That is, flotation air is induced and dispersed into the slurry by the self-aspirating agitator.

[0046] A supporting frame 35 is positioned above each flotation cell 2 to support the mechanical agitator 20, and take the form of in the form of bridge beams as best shown in Figures 2 and 3. Also, each flotation cell 2 further includes an aeration system including an air blower and a fluid conduit (not shown) to direct air from the blower into the rotor 22. The fluid conduit is defined in part by an axial bore 33 extending through the drive shaft 24 into the rotor 22.

[0047] Turning now to describe the operation of the flotation device 1 in more detail, slurry is initially fed into the first flotation cell 2 via a feed inlet 38, from where it flows toward the mechanical agitator 20. The rotating action of the rotor 22 induces a flow through the agitator mechanism that continuously recirculates the slurry at the bottom of the cell 2 to maintain the particles in suspension. The aeration system continuously disperses air into the rotor 22 to form fine bubbles which collide with and adhere to the fine valuable mineral particles in the slurry and subsequently float to the top of the cell 2 to form a mineral enriched surface froth. As the froth floats toward the surface, it is directed radially outwardly by the deflection cone 28 for recovery through the overflow launder 29 located near the top of the cell 2. Where the mechanical agitator 20 is a self-aspirating agitator, there is no need for an aeration system since the self-aspirating agitator will generate air to aerate the slurry.

[0048] Unlike conventional flotation devices, the bulk of the coarse solids in the slurry will flow through the lower or bottom opening 4 into the next flotation cell 2 due to the hydraulic gradient and gravity. Again, the slurry is subjected to agitation and aeration to generate froth containing finer mineral particles that are recovered by the launder 29 while the bulk of the slurry (gangue) passes through the lower opening 4 into the next or successive flotation cell 2. At the last flotation cell 2, the slurry exits the flotation device 1 through the discharge outlet 7 for further processing.

[0049] As a consequence, the flotation device 1 allows much coarser (i.e. larger sized) material of up to 2 mm in maximum size to be transported through the flotation cells since the majority of the slurry flow does not need to rise up through a vertical duct and overflow the weir to reach the next cell in the bank, as is required in conventional flotation banks. Instead, the hydraulic gradient is always present in the flotation device 1 that will push the coarse material from one cell to the next and eventually to the discharge outlet 7. Accordingly, each flotation cell 2 does not require any feed box, transfer duct, downflow duct or valve spool pieces to transfer slurry between cells that is usually required in conventional arrangements where flotation cells are connected in series to each other. Thus, the flotation device 1 is able to avoid coarse material creating blockages between flotation cells and "sanding up" the flotation device 1. In contrast, a series of flotation cells that are interconnected by a feed box, transfer duct, a downflow duct with dart valves or valve with spool pieces between each cell are subject to sanding in these areas, resulting in the problems of shutdown of the flotation cells for cleaning and maintenance and consequential loss in efficiency. The flotation device 1 only has to suspend these coarser solids inside each flotation cell 2 and the majority of the slurry will transfer from one cell to the next cell via the lower or bottom opening 4.

[0050] In contrast, in a conventional flotation device having a bank or row of cells all at the same floor level, there is a longer horizontal transport distance that coarse particles must travel. Also, there is very little hydraulic driving head, and so there is no impetus for the coarse solids in the slurry to flow through each cell in the bank or row. Thus, the conventional flotation device is unable to process coarse solids larger than 0.25 mm in a continuous process.

[0051] Another advantage of the invention is that the flotation device is able to process particles having a certain size distribution ranging from small fine particles less than 0.15 mm in diameter, to particles of 0.15 to 0.25 mm in diameter and up to coarse sized particles having maximum diameter sizes of 2mm. Hence, if a coarser feed above this maximum particle size of 0.15 to 0.25mm was introduced or the gangue minerals were of high specific gravity, then the coarser particles would still be processed by the flotation device 1, and thus reduce the risk of the openings 4 and discharge outlet 7 "sanding up" and stopping the flow through the flotation device. Thus, the effect of the invention would be a reduced shutdown of the flotation device 1, the ability to process particles up to 2 mm in maximum diameter and an increase in the efficiency of the flotation device 1 and its associated flotation process.

[0052] In contrast, in a conventional bank of flotation cells, the coarser feed above the maximum particle size of 0.15 to 0.25 mm or the gangue minerals being of high specific gravity would result in sanding up of the cells, requiring a shutdown of the bank so that the cells can be "flushed out" to remove the blockage, consequently reducing the efficiency of the flotation device and its associated flotation process. Thus, for a conventional bank of flotation cells the risk of sanding up of the entire bank of cells severely limits the overall particle size range that can be treated by the flotation process.

[0053] While most of the coarse particles will pass through each flotation cell 2, in operation there may be some sanding in the corners of each flotation cell where the particles are significantly larger, just above 2 mm. The overall volume will reduce slightly, by 10 to 15 %, but this minor sanding issue will not adversely affect operation of the flotation device 1. The volume of slurry in each flotation cell 2 may simply be adjusted to account for this minor sanding.

[0054] It will also be appreciated that the invention can be readily scaled to provide a flotation device with individual flotation cells that have a relatively small or high volume. For example, the invention can provide a flotation device having flotation cells with relatively small volumes of 0.5 to 2.8 m^3. In another example, the invention provides a flotation device having flotation cells with relatively high volumes, ranging from 630 m^3 to 800 m^3 and up to 1000 m^3.

[0055] In addition, the ability of the flotation device 1 to process coarser sized particles means that there is significantly less power consumption in the grinding circuit since there is no longer a need to grind all the ore to a smaller particle size to enable processing through the flotation device. In other words, the P80 of the product size produced from the grinding circuit can be increased significantly. It will be understood by one skilled in the art that P80 means that 80 % of the particles pass through a nominated screen mesh size. For example, a P80 = 600 µm means that 80 % of all particles present will pass through a 600 µm screen aperture. The increase in P80 for the product size means that an ore only has to be ground sufficiently in the grinding circuit to release only the valuable minerals and not all of the gangue material has to ground. In comparison, it was required to grind the entire ore in order for the material to be within the conventional particle size limits to pass through a conventional flotation circuit or device without sanding up and keep the ore fully suspended through the flotation process.

[0056] In addition, the ability of the flotation device 1 to process coarser sized particles means that the particle size distribution in the feed slurry may vary more widely than conventionally permitted. Particle size distribution is determined by P80 and D50. As understood by one skilled in the art, a D50 means that 50 % of all particles present will pass through a nominated screen mesh size. For example, a D50 = 500 µm means that 50 % of all particles present will pass through a 500 µm screen aperture. Hence, the P80 and D50 provide the particle slurry profile and hence the particle size distribution. The invention thus permits the flotation device to process coarser sized mineral particles having a wider particle size distribution of P80 ≤ 2 mm and D50 ≤ 1000 µm. Some typical examples of particle size distributions for coarser sized mineral particles that can be processed by the flotation device according to the invention are set out in Table 1 below:

Table 1

P80 (µm)	250	500	750	1000	1250	1500	1750	2000
D50 (µm)	108	216	325	433	542	650	758	867

[0057] Another embodiment of the invention is illustrated in Figure 5, where corresponding features have been given the same reference numerals. In this embodiment, the slurry transfer means takes the form of an inclined pipe 39 that is in fluid communication with each lower opening 4 and entry opening 4a of each flotation cell 2. The pipe 39 is preferably inclined at least 10°, most preferably 15°, to facilitate unimpeded slurry flow between adjacent flotation cells 2 and minimise, hinder or prevent sanding up occurring between the cells. In all other respects, this embodiment acts in the substantially same way as the embodiment of Figures 1 to 3. In some embodiments, the slurry transfer means takes the form of a conduit instead of pipe 39, and may include a channel.

[0058] In some embodiments, the lower opening 4 includes a valve to control the flow rate of the slurry. For example, in the embodiment of Figures 1 to 3, the lower opening takes the form of a gate that is provided in an upstream flotation cell to control the flow rate of the slurry, as best shown in Figures 1 and 6a, where corresponding features have been given the same reference numerals. The gate in the upstream flotation cell 2a is in the form of a slide gate 40 that is operatively connected to a valve actuator 42 via a shaft 44. In yet another embodiment, a flexible sleeve with a flow control valve is used in a downstream flotation cell to control the flow rate of the slurry, as illustrated in Figure 6b, where corresponding features have been given the same reference numerals. The flexible sleeve in this embodiment takes the form of a rubber nozzle sleeve 45 that is opened and closed using a pinching valve 47 operatively connected to the valve actuator 42 via the shaft. In some embodiments, the lower opening 4 takes the form of a sand gate, which controls the slurry flow from one flotation cell to the next successive flotation cell. In each of these described embodiments, the slide gate 40, pinch valve arrangement 45, 47 and sand gate controls the slurry flow so that there is a constant pulp level in each flotation cell. Thus, the slide gate 40, pinch valve arrangement 45, 47 and sand gate are used to maintain a set slurry level. In addition, the slide gate 40, pinch valve arrangement 45, 47 and sand gate each maintains a set froth thickness to control the flotation process.

[0059] In addition, it will be appreciated that manually operable or automated gates and weirs can be utilised in various embodiments of the invention for the opening. In the case of automated gates, a computerised control system, such as a remotely located DCS control system, controls operation of the gate so as to control the pulp level and froth depth in each flotation cell 2.

[0060] In some embodiments, the angle of inclination α is between 10° and 65°, preferably between 13° and 50°, and more preferably between 15° and 45° to induce the hydraulic gradient.

[0061] In some embodiments, the angle of inclination α is between 10° and 18° to induce the hydraulic gradient. In a preferred embodiment, said angle of inclination is 15°.

[0062] In some embodiments, there is an average angle of inclination measured from the floor of a first flotation cell in said flotation device to the floor of the last flotation cell in the flotation device, said average angle of inclination inducing the hydraulic gradient and the average angle of inclination being at least 10°, preferably 15°. In further embodiments, the average angle of inclination being between 10° and 60°, more preferably between 15° and 45°.

[0063] While the embodiments of the invention have been illustrated as comprising three flotation cells 2, it will be appreciated that the invention can be implemented with at least two flotation cells, at least four flotation cells or any number of flotation cells.

[0064] In other embodiments, the floors 9 of the flotation cells 2 are not necessarily planar but instead can be curved, inclined, U-shaped, V-shaped or have any other polygonal shape. Also, only a part of the floor and not the entire floor may have one of the above shapes. Examples of possible floor shapes are shown in Figures 7a to 7e, where Figure 7a shows a floor 9 that is curved or U-shaped, Figure 7b shows a floor 9 that is V-shaped, Figure 7c shows a floor 9 that is inclined, Figure 7d shows a floor 9 that is partly curved and Figure 7e shows a floor 9 that is partly inclined. The curved and inclined portions of the floor 9 in Figures 7d and 7e can be located in other positions than towards one end of the cell 2, such as in the middle of the floor 9 or in the floor offset from a centreline of the cell.

[0065] The invention is particularly useful in processing mineral ore particles, which typically have densities of at least 2000 kg/m^3, such as quartz ore (around 2650 kg/m^3) and iron ore (around 6500 kg/m^3). Other suitable mineral ores include copper, nickel, zinc, lead, gold, silver, platinum and other metal ores.

[0066] It will further be appreciated that any of the features in the preferred embodiments of the invention can be combined together and are not necessarily applied in isolation from each other. For example, the feature of a laminar flow mixer for the mechanical agitator can be combined with the feature of rectangular or square walls 8 for the flotation cell 2. Similar combinations of two or more features from the above described embodiments or preferred forms of the invention can be readily made by one skilled in the art.

[0067] By providing a flotation device having flotation cells with a slurry transfer means for passing slurry through the flotation device unimpeded and floors that are gradually lower in each flotation cell to form an angle of inclination of at least 10° that creates a hydraulic gradient, the invention confers the primary advantages of being able to process slurry having coarser particles having maximum sizes of up to 2mm in contrast to conventional limits of 0.25 mm and a particle size distribution of P80 ≤ 2 mm and D50 ≤ 900 µm. In particular, in one embodiment, this advantage is further enhanced by the angle of inclination being in the range of 10° to 18°, most preferably 15°. In addition, this has a flow on effect in reducing the power consumption of the upstream grinding circuit as there is no need to grind the ore to a smaller particle size to be processed in the flotation device of the invention. Furthermore, since there is a direct connection between adjacent flotation cells, the likelihood of sanding up the flotation device is reduced by eliminating all transfer ducts or connecting spool pieces between the flotation cells, thus avoiding any blockages caused by movement of the coarser material in the slurry. All these advantages of the invention result in more efficient operation of both the grinding circuit and the flotation circuit using the flotation device of the invention by reducing overall power consumption, processing of slurry having larger (coarser) maximum particle sizes and reducing shutdowns caused by sanding of the flotation circuit. In all these respects, the invention represents a practical and commercially significant improvement over the prior art.

[0068] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

CLAIMS

1. A flotation device for processing a slurry comprising coarser sized mineral particles, comprising:

a plurality of flotation cells in fluid communication with each other;

an inlet for receiving said slurry into one of said flotation cells;

wherein each said flotation cell has a wall with a lower opening that permits said slurry to pass from a preceding flotation cell into an entry opening of a successive flotation cell;

a slurry transfer means in fluid communication with said lower opening and said entry opening to facilitate unimpeded slurry flow; and

wherein a floor of each said successive flotation cell is lower than a floor of said preceding flotation cell to create an angle of inclination of at least 10° to induce a hydraulic gradient to drive said slurry to a discharge outlet of said flotation device.

2. The flotation device of claim 1, wherein said angle of inclination is between 10° and 65°, preferably between 13° and 50°, more preferably between 15° and 45°, and most preferably is 15° to induce said hydraulic gradient.

3. The flotation device of any one of the preceding claims, wherein there is an average angle of inclination measured from the floor of a first flotation cell in said flotation device to the floor of the last flotation cell in said flotation device, said average angle of inclination inducing said hydraulic

gradient and said average angle of inclination being at least 10°, between 10° and 60°, preferably between 13° and 50°, more preferably between 15° and 45°, and is most preferably 15°.

4. The flotation device of any one of the preceding claims, wherein there is a stepwise drop in said floor of said successive flotation cell relative to said floor of said preceding flotation cell, to create said angle of inclination between adjacent cells.

5. The flotation device of claim 4, wherein said stepwise drop is between 300 and 5000 mm, preferably 600 and 3300 mm.

6. The flotation device of any one of the preceding claims, wherein there is a stepwise drop in the top of said successive flotation cell relative to the top of said preceding flotation cell, to create said angle of inclination between adjacent cells.

7. The flotation device of any one of the preceding claims, wherein said flotation cells do not vary in height by more than 15 %, preferably 10 %.

8. The flotation device of any one of the preceding claims, wherein said flotation cells do not vary in width or diameter by more than 15 %, preferably 10 %.

9. The flotation device of any one of the preceding claims, wherein the height to width ratio of said flotation cells does not vary by more than 15 %.

10. The flotation device of any one of the preceding claims, wherein said slurry transfer means comprises a common wall shared by adjacent flotation cells to minimise blockages in said lower opening and said entry opening, said lower opening and said entry opening being formed in said common wall.

11. The flotation device of any one of claims 1 to 8, wherein said slurry transfer means comprises a wall from each adjacent flotation cell joined together, preferably a portion of a side wall of each adjacent flotation cell connected together, to minimise blockages in said lower opening and said entry opening.

12. The flotation device of any one of claims 1 to 9, wherein said slurry transfer means comprises an inclined conduit or pipe interconnected said lower opening and said entry opening to facilitate unimpeded slurry flow and minimise blockages in said lower opening and said entry opening.

13. The flotation device of any one of the preceding claims, wherein said slurry flows unidirectionally in said flotation device from said preceding flotation cell to each successive flotation cell to minimise blockages in said lower opening and said entry opening.

14. The flotation device of any one of the preceding claims, wherein each said flotation cell comprises a mechanical agitator for agitating said slurry.

15. The flotation device of claim 14, wherein said mechanical agitator comprises a rotor and a stator.

16. The flotation device of claim 14, wherein said mechanical agitator comprises a laminar flow mixer.

17. The flotation device of any one of claims 14 to 16, wherein said mechanical agitator is connected to an aeration system for aerating said slurry and generating said froth.

18. The flotation device of claim 14, wherein said mechanical agitator comprises a self-aspirating agitator to generate air to aerate the slurry.

19. The flotation device of any one of the preceding claims, wherein the floors of said flotation cells are the same to create uniform angles of inclination between each adjacent flotation cells.

20. The flotation device of any one of the preceding claims, wherein at least one floor of the floors of said flotation cells, or part of said at least one floor, is curved, planar, inclined, U-shaped or V-shaped.

21. The flotation device of any one of the preceding claims, wherein there are at least two flotation cells, preferably at least three flotation cells and more preferably at least four flotation cells.

22. The flotation device of any one of the preceding claims, wherein the coarser sized mineral particles have a P80 of 250 µm to 2 mm, preferably 300 µm to 1500 µm, more preferably 350 µm to 1000 µm and most preferably 500 µm to 750 µm, and a D50 of 100 µm to

1000 µm, preferably 150 µm to 750 µm, more preferably 175 µm to 500 µm and most preferably 200 µm to 300 µm

23. The flotation device of any one of the preceding claims, wherein said flotation cells each have a volume of 630 m^3 to 800 m^3, preferably up to 1000 m^3.

24. Use of a flotation device according to any one of the preceding claims to process a slurry comprising coarser sized mineral particles having a P80 of 250 µm to 2 mm, preferably 300 µm to 1500 µm, more preferably 350 µm to 1000 µm and most preferably 500 µm to 750 µm, and a D50 of 100 µm to 1000 µm, preferably 150 µm to 750 µm, more preferably 175 µm to 500 µm and most preferably 200 µm to 300 µm.

25. A method of processing a slurry comprising coarser sized mineral particles in a flotation device comprising a plurality of flotation cells in fluid communication with each other, wherein each said flotation cell has a lower opening and an entry opening, an inlet for receiving said slurry into one of said flotation cells, a discharge outlet, and a slurry transfer means in fluid communication with said lower opening and said entry opening, said method comprising the steps of:

introducing said slurry through said inlet;

permitting said slurry to pass from a preceding flotation cell through said lower opening via said slurry transfer means into said entry opening of a successive flotation cell; and

arranging said flotation cells so that a floor of each said successive flotation cell is lower than a floor of said preceding flotation cell to create an angle of inclination of at least 10° to induce a hydraulic gradient to drive said slurry to said discharge outlet.

26. The method of claim 25, wherein said angle of inclination is between 10° and 65°, preferably between 13° and 50°, more preferably between 15° and 45° and most preferably is 15° to induce said hydraulic gradient.

27. The method of claim 25 or 26, wherein there is an average angle of inclination measured from the floor of a first flotation cell in said flotation device to the floor of the last flotation cell in said flotation device, said average angle of inclination inducing said hydraulic gradient and said average angle of inclination being at least 10°, preferably between 10° and 60°, more preferably between 13° and 45°, and most preferably 15°.

28. The method of any one of claims 25 to 27, wherein the coarser sized mineral particles have a P80 of 250 µm to 2 mm, preferably 300 µm to 1500 µm, more preferably 350 µm to 1000 µm and most preferably 500 µm to 750 µm, and a D50 of 100 µm to 1000 µm, preferably 150 µm to 750 µm, more preferably 175 µm to 500 µm and most preferably 200 µm to 300 µm.

29. The method of any one of claims 25 to 28, wherein said coarser sized mineral particles are mineral ore particles having a density of at least 2000 kg/m^3.

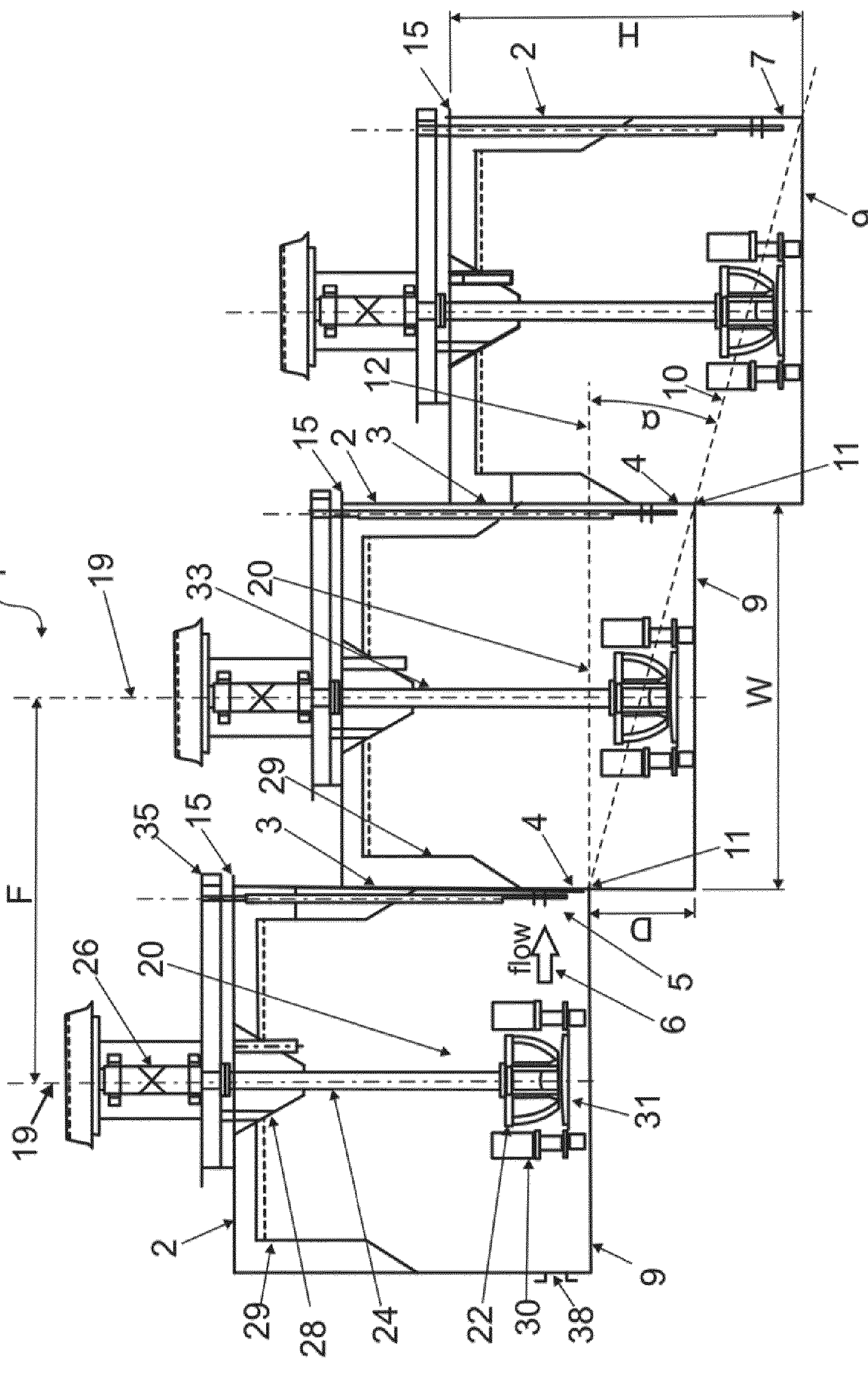

Fig. 1

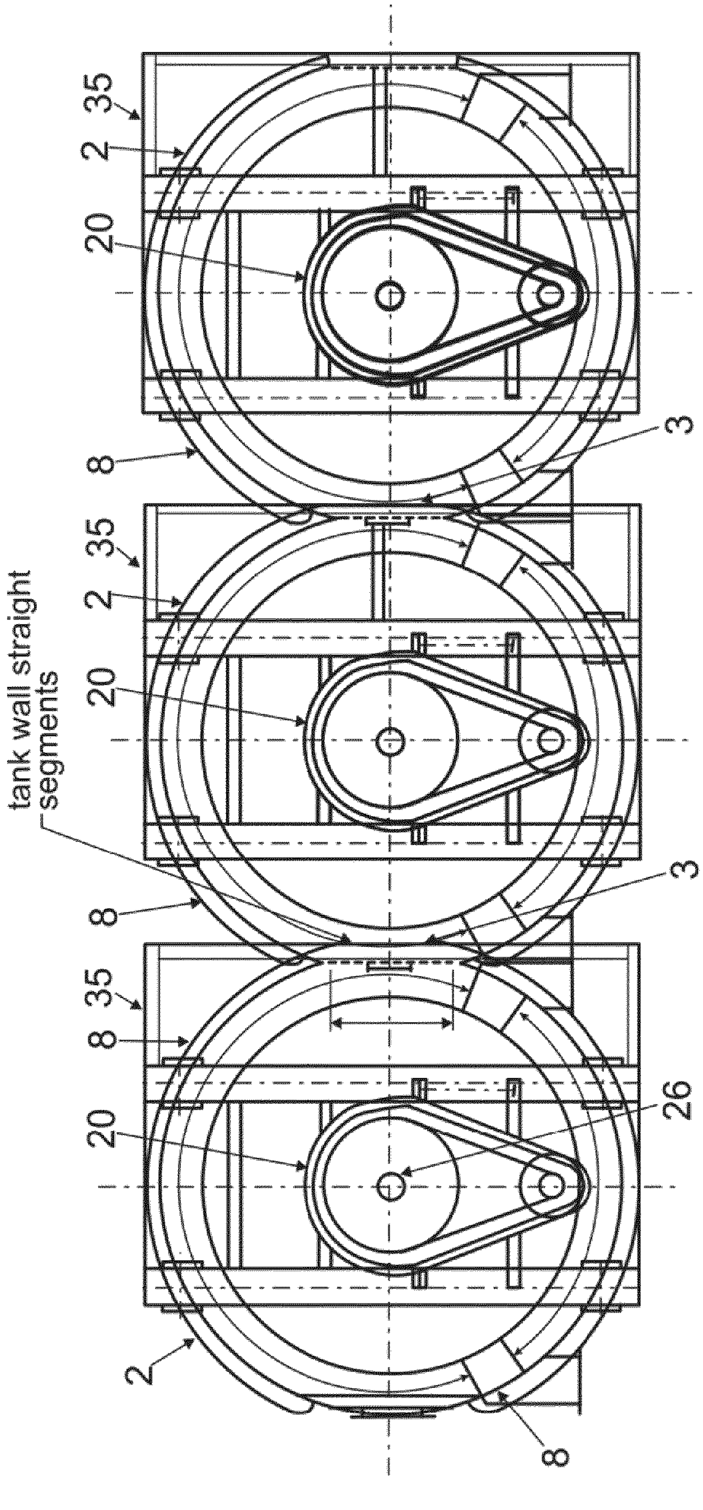

Fig. 2

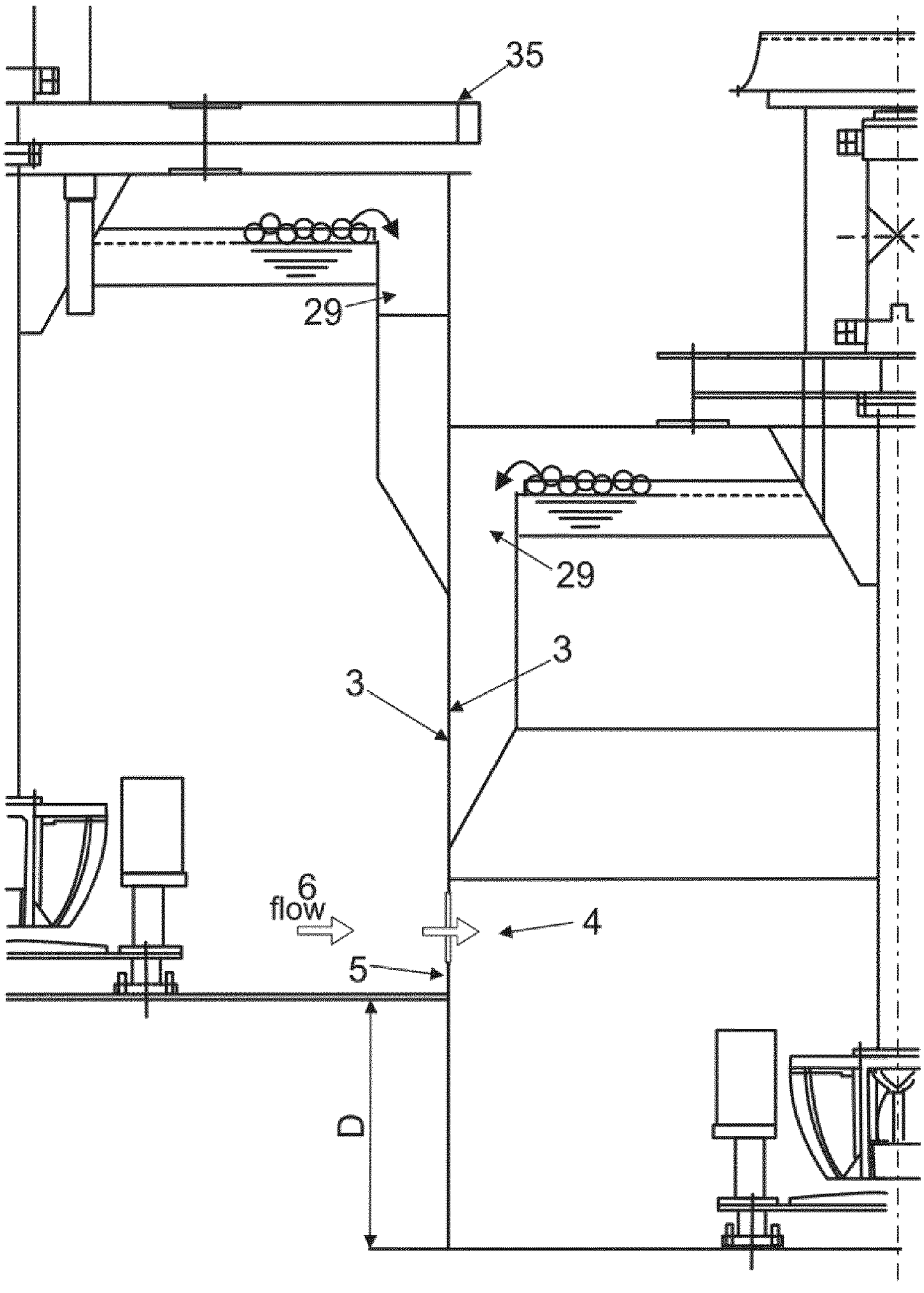

Fig. 3

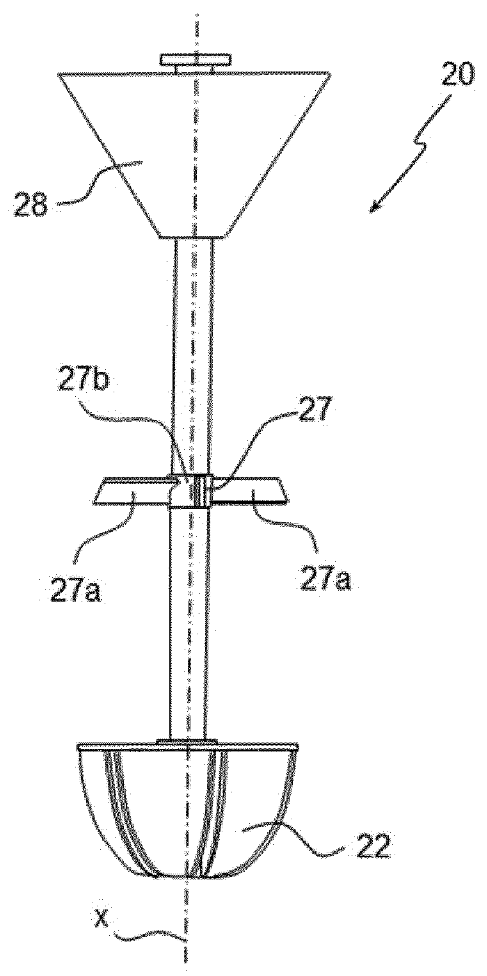

Fig. 4

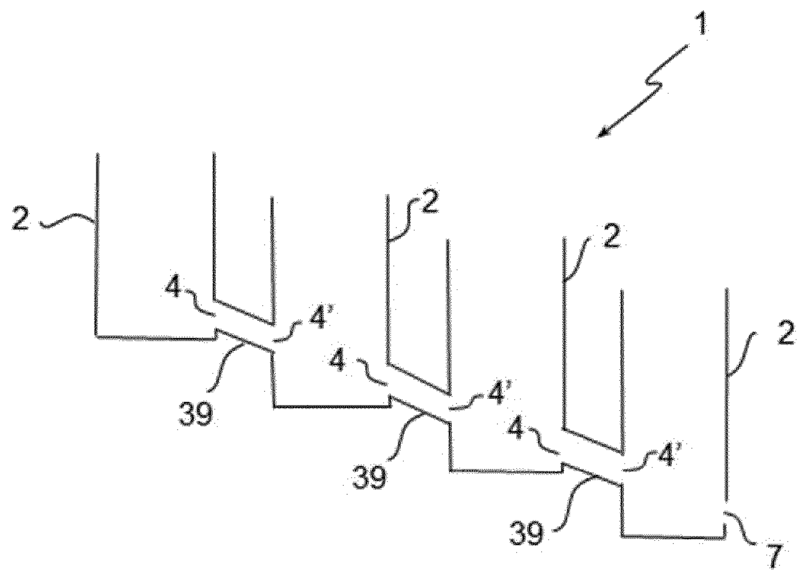

Fig. 5

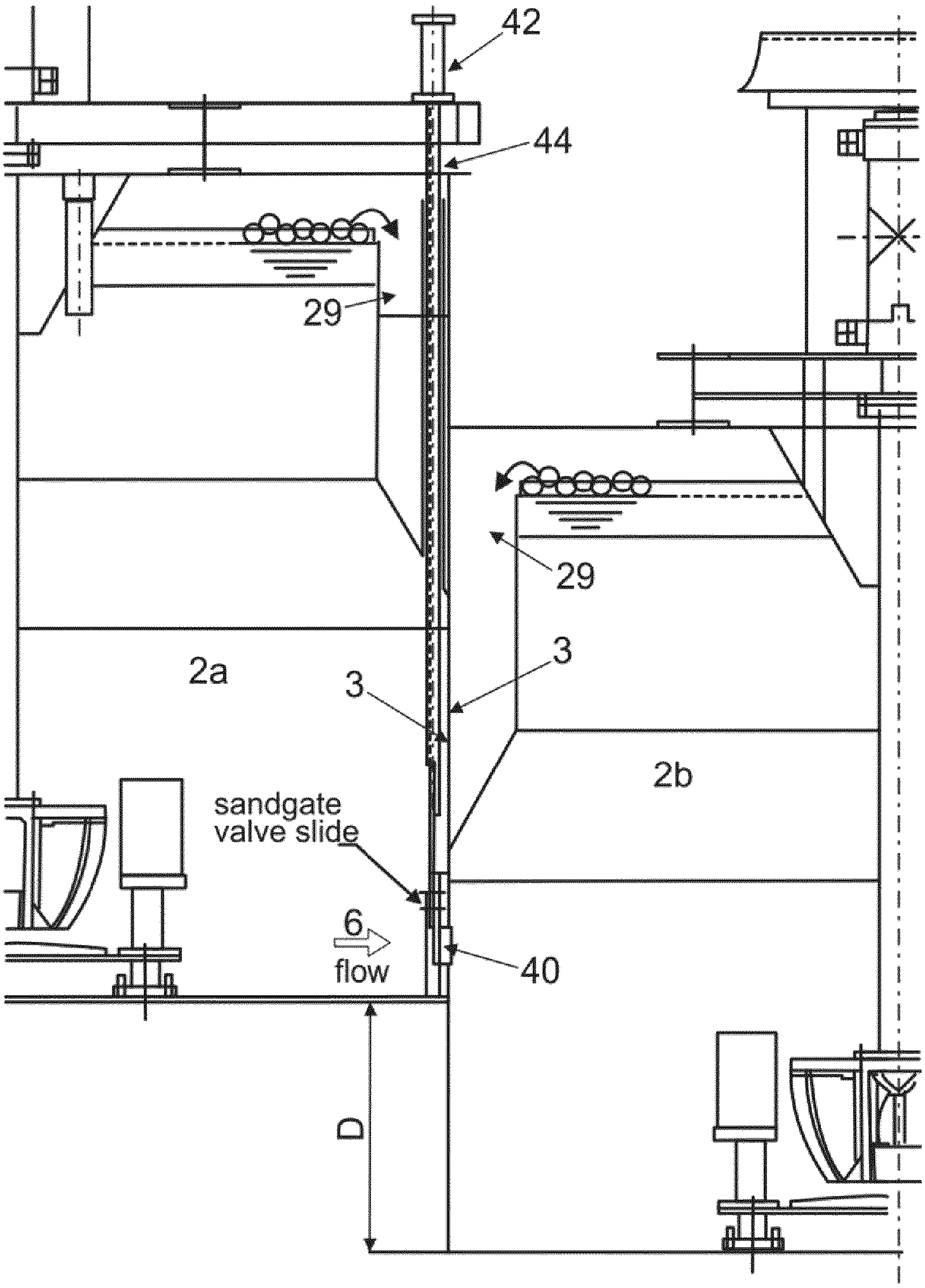

Fig. 6a

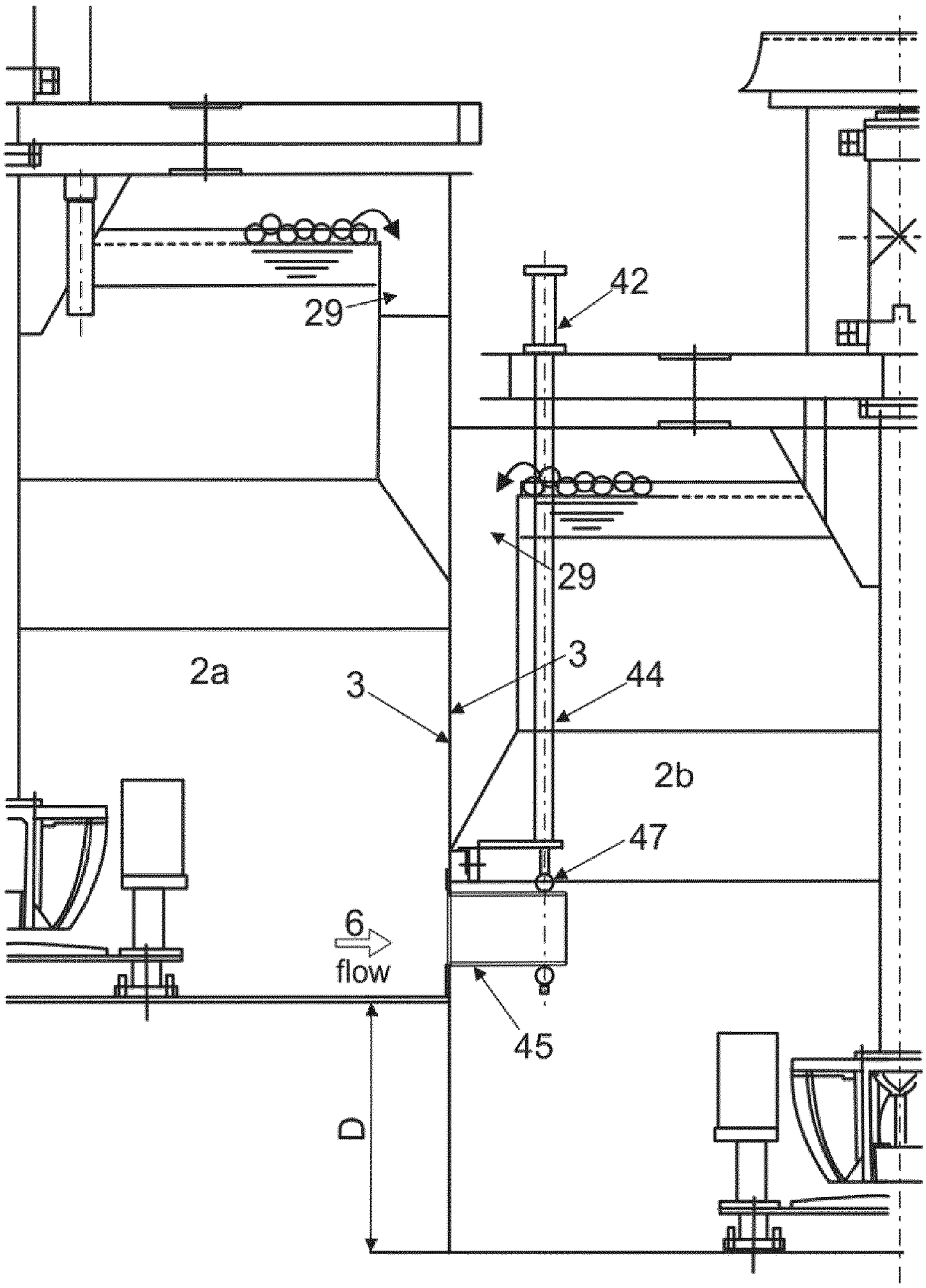

Fig. 6b

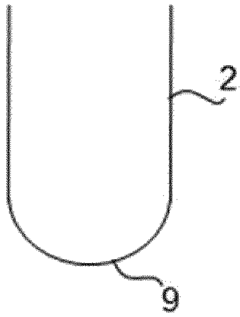

Fig. 7a

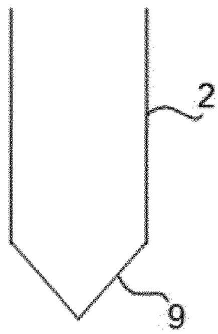

Fig. 7b

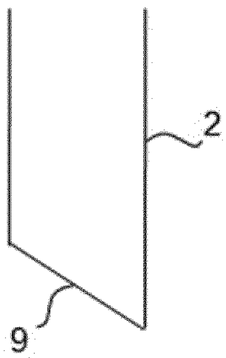

Fig. 7c

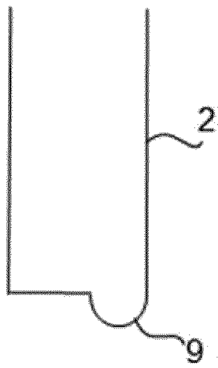

Fig. 7d

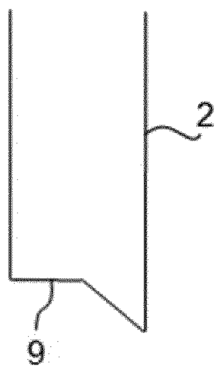

Fig. 7e

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2016/050100

A. CLASSIFICATION OF SUBJECT MATTER
INV. B03D1/14 B03D1/16
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 1 328 456 A (ROSS, JAMES D.) 20 January 1920 (1920-01-20) page 1 - page 2; figures 1,2	1-29
X	GB 1 287 274 A (WESTINGHOUSE ELECTRIC CORP [US]) 31 August 1972 (1972-08-31) page 2 - page 4; figure 2	1-29
X	US 1 415 105 A (MOFFAT DAVID D) 9 May 1922 (1922-05-09) page 2, line 55 - line 71; figure 2	1-29
X	GB 1 052 116 A (NAKAMURA, KOICHI) 8 February 1964 (1964-02-08) page 2 - page 4; figures 1-8	1-29
X	US 5 965 857 A (HUGHES STEPHEN [AU]) 12 October 1999 (1999-10-12) column 4 - column 5; figures 5,6	1-29

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 April 2016	17/05/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Roider, Josef

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/FI2016/050100

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